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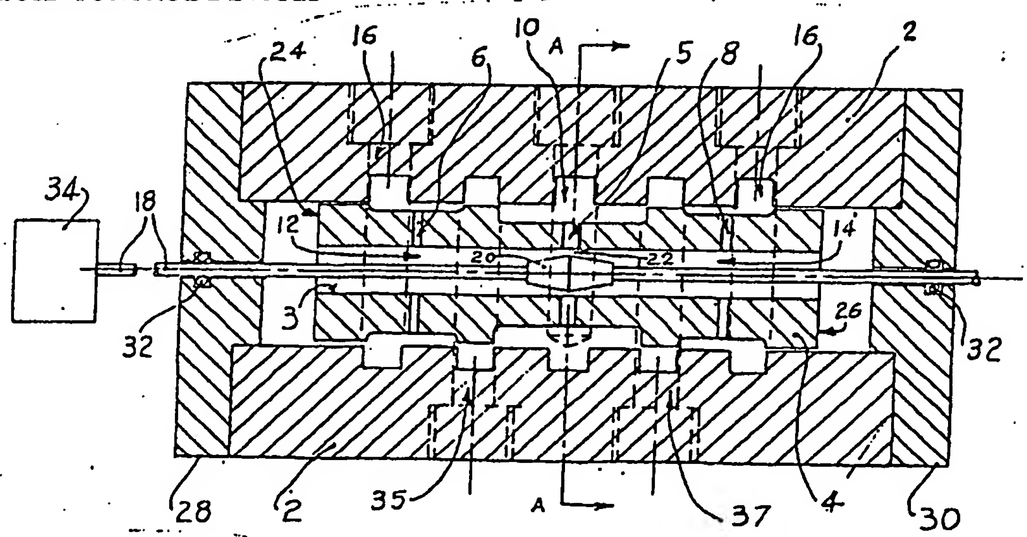

Section B.B.

(57) Abstract

A fluid control device of the sliding spool type having pilot control wherein a control profile (20) is located in a longitudinal bore through the spool (4) and has radial clearance (22) in said bore. The control profile (20) separates respective control chambers (12, 14) which extend to the main bore in which the spool is located and an orifice arrangement (5) in the wall of said spool (20) directs secondary fluid flow from a pressure port (10) onto said control profile and into said chambers (12, 14) whereby an imbalance in the chamber pressures will cause sliding movement of the spool. Further respective orifices (6, 8) allow said secondary flow to return to the low pressure side of a fluid supply. The control profile (20) is arranged on a rod which extends externally of the body of the device and sliding movement of the rod causes imbalance of a hydraulic Wheatstone bridge formed by the orifices (5, 6, 8) in combination with the control profile (20) whereby the bridge tends towards equilibrium causing the spool (4) to follow movement of said control profile (20) in a force feedback gain manner. The device has a position feedback ratio of 1:1.

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This invention relates to fluid control devices such as hydraulic or pneumatic control valves, servovalves and position control devices and in particular relates to such devices of the sliding spool type which are pilot operated to facilitate better response, control of large flow capacities and/or control from remote controlling means. The remote controlling means may be mechanical, electromechanical, electrohydraulic, fluidic or electronic or any combination thereof, be it proportional control, analogue, digital, mark/space ratio or otherwise.

Various forms of pilot operated valves are well known and by far the most common has a sliding spool pilot valve perched on top of the main control valve in a "piggy-back" fashion. The pilot spool has also been placed inside a bore of the main control valve spool. An inherent problem or disadvantage with sliding spool type valves is the high degree of accuracy required in manufacture due to the fine tolerances required between the sealing lands of the spool and the bore in which the spool is adapted to slide. These fine tolerances render spool type valves expensive to manufacture and furthermore, the spool is a delicate piece of apparatus which must be handled with extreme care and replaced if damage or wear affects the fine tolerances. The aforementioned problems are compounded when the pilot valve is also of the spool type as the same criticality of tolerances applies to the pilot valve. Other types of pilot valves such as slide valves, flapper valves, nozzle-jets or variations of each are well known and have various different characteristics which render them suitable in some situations and not in others. However, the fine tolerances required with these other types of pilot valves requires at least the same high degree of accuracy in manufacture as with spool type valves and thus there are no real gains to be made from a cost consideration as between the various

alternatives. The choice thus usually depends on the particular requirements of the control, be it on-off control, proportional control or servo-control, for example, and whatever the choice the cost of such control is relatively expensive.

The object of this invention is to provide an improved control arrangement for a spool type control valve which is more economical to manufacture than existing arrangements.

It is a further object to provide an improved control arrangement for a spool type control valve which facilitates on-off, proportional and/or servo-control of a fluid medium. It should be noted that these latter two types of control are not conveniently achievable with spool type pilot valves.

Accordingly the invention provides a fluid control device of the sliding spool type wherein a spool having various lands is adapted to slide within the bore of a body part to facilitate primary fluid flow between various main ports in said body part dependent upon the position of said spool, said spool having a longitudinal bore extending therethrough and means within said spool bore to facilitate fluid controlled movement of said spool, characterized in that, said means comprises a control profile having radial clearance in said spool bore and separating respective control chambers, each control chamber includes part of the bore of said body part whereby pressurized fluid in said control chambers exerts forces or respective ends of said spool, a first orifice arrangement is provided in said spool to facilitate secondary fluid flow from a pressure port of said main ports, through the wall of said spool and onto said control profile whereby said secondary flow is directed into respective said control chambers and, via further respective orifice arrangements, back to the low pressure side of a fluid supply such that said device is caused

to act as a Wheatstone bridge tending towards equilibrium whereby said spool follows movement of said control profile along said spool bore in a force feedback gain manner due to imbalance of pressures in respective said control chambers.

In order that the invention may be more readily understood a particular embodiment of a hydraulic control valve will now be described with reference to the accompanying drawings wherein:

FIG. 1 is a sectional side elevation of the hydraulic control valve taken in a longitudinal direction through the valve body,

FIG. 2 is a part sectional view taken on the lines A-A of FIG. 1,

FIG. 3 is a part sectional view similar to FIG. 1, showing fluid pressures and flows with the control element in the neutral position,

FIG. 4 is similar to FIG. 3 showing the fluid pressures and forces acting on the spool when the control element is in the neutral position, and

FIG. 5 is similar to FIGS. 3 and 4 showing the fluid pressures and forces acting on the spool when the control element is displaced from the neutral position.

Referring now to the drawings, it can be seen that the control valve consists essentially of a valve body 2 and a control spool 4 which slides within a central bore through the body 2. The control spool 4 has a series of lands around the outer surface thereof and a central bore 3 which extends longitudinally through the spool. Five ports are arranged in the body 2 and communicate with various chambers which surround the spool. These ports comprise a pressure port 10, two tank ports 16 and outlet –

ports 35 and 37. The control valve as described to date is essentially the same as any number of conventional directional control valves and servo valves.

The valve body 2 has respective end plates 28,30 which seal the respective ends of the central bore of the valve body and a control rod 18 passes through a suitable aperture in each end plate 28,30 and is sealed therein by a suitable "O" ring 32 at each end plate. The control spool 4 has an orifice 5 extending through the wall thereof on both sides of the central bore 3. The orifice 5 is arranged midway between the ends of the control spool 4. Identical orifices 6 and 8 are arranged towards respective ends of the control spool 4. Each orifice 6 and 8 extends through the wall of the control spool 4 on opposite sides of the central bore 3. The orifices 6 and 8 are smaller in diameter than the orifice 5 and all three extend radially. The orifice 5 is termed an inlet control orifice and the orifices 6 and 8 are termed outlet control orifices. The inlet control orifice 5 connects at all times to pressure port 10 and each outlet control orifice 6 and 8 communicate with respective tank ports 16 at all times. The inlet control orifice 5 and the outlet control orifices 6 and 8 thus provide a continuous flow of hydraulic fluid into, and out of, the respective control chambers 12 and 14 within the central bore 3 of the spool 4. The control chambers 12 and 14 are separated by a control profile 20 located on the control rod 18 and formed integrally therewith or suitably attached thereto.

A radial clearance 22 exists between the control profile 20 and the internal surface of central bore 3 of the control spool 4. The clearance 22 allows continual secondary flow of fluid from the pressure port 10 through the inlet orifice 5 to control chambers 12 and 14 respectively and finally through each outlet control orifice 6,8 to the tank ports 16.

The sizes and numbers of orifices 5, 6 and 8, the amount of radial clearance 22, and the shape of profile 20, are chosen so as to maintain suitable fluid pressures in control chambers 12 and 14 and such pressures are designated P_1 and P_2 respectively as shown in FIG. 3. Pressure P_1 acts at all times on face 24 of the control spool 4 and pressure P_2 acts at all times on face 26 of the spool 4. When the control spool 4 is at rest within the body 2, the pressures P_1 and P_2 and any flow forces are in equilibrium. When the equilibrium is upset by changes in pressures P_1 and P_2 or flow forces, the control spool 4 will move to restore the equilibrium. The resistance to secondary fluid flow due to the shape of the control profile 20 and the shape and position of the orifices 5, 6 and 8 causes the valve to act as a hydraulic Wheatstone bridge tending always towards equilibrium.

Control input to the control rod 18 is provided by a suitable externally mounted transducer 34, which may take any of various known formssuch as manual, mechanical, electromechanical, electrohydraulic, electronic, fluidic or a combination thereof.

In use the device operates as follows. High pressure fluid is supplied to pressure port 10 and flows through the inlet control orifice 5 to the control chambers 12 and 14 on respective sides of the control profile 20. The fluid then flows through the outlet control orifices 6 and 8 to the tank ports 16. Due to the small size of the orifices 5, 6 and 8, in comparison with the main passages of the control valve, the fluid flow rates through the control chambers 12 and 14 are only a fraction of the fluid flow rates through the control valve main ports 35, 37, 10 and 16.

Referring to FIG. 4, when the control profile 20 is held in position symmetrically opposite to orifice 5, the resistance to flow into chamber 12 is equal to the

resistance to flow into chamber 14. Thus, the pressures P_1 and P_2 are equal and the control spool 4 will be at rest. In practice, the actual rest position of the control spool 4 will be dependent on manufacturing tolerances and forces due to fluid flow through the control valve, that is flow forces. Thus the position of the control profile 20 will be such that forces f_1 and f_2 due to pressures P_1 and P_2 and flow forces acting on control spool 4 will be in equilibrium. The pressure area of the control rod 18 is equal to the difference between the cross-sectional area of the control profile 20 and the cross-sectional area of the control rod 18 and if the pressure area on each side of the control profile 20 is equal the force f is zero.

Referring now to FIG. 5, the control profile 20 is shown displaced in relation to the orifice 5. The resistance to flow into chamber 12 is larger than the resistance to flow into chamber 14 and thus pressure P_1 in control chamber 12 is less than pressure P_2 in control chamber 14. The force f_2 acting on the control spool 4 due to pressure P_2 is thus larger than force f_1 due to pressure P_1 and the control spool 4 will therefore move to a position whereby the orifice 5 is centrally located relative to the control profile 20. In other words, the control spool 4 will move to re-establish equilibrium of forces f_1 and f_2 and equilibrium of the flow forces.

The speed of response of the control spool 4 to the positional change of control rod 18 and thus the position of control profile 20, is a function of the sizes of the various orifices and the shape of the control profile 20.

It should be evident from the description hereinabove that the fluid control device according to the present invention provides an improved arrangement which allows the operation of large flow capacity valves which require considerable force to shift the controlled member

(control spool). The device according to this invention is convenient to manufacture because there are no critical tolerances as between the control profile 20 and the inner surface of the bore through the control spool 4. Movement of the control rod 18 does not require a significant force in relation to the forces required to move the control spool 4 and thus the rod may be moved by any convenient transducer means 34 adapted to provide the necessary control to operate the spool 4 in the manner required. In other words, the valve has a high gain force feedback. The control spool 4 has various lands which are arranged in relation to the inlet and outlet ports to provide whatever necessary control is required at some remote machine location. The invention thus provides a low cost and simple two stage operation of valves and position control devices and eliminates the conventional pilot spool controls with their inherent disadvantages. It should be noted that the control valve described provides a 1:1 ratio position feedback and can be readily adapted to provide on-off control, proportional control and/or servo control as required. The valve described may be conveniently adapted for continuous control in an automatic manner such that continuous control of proportion control valves, servo valves and position control devices is readily attainable.

Clearly various modifications may be readily provided without departing from the spirit or scope of the invention. The orifices 5, 6 and 8 may in fact comprise a series of radially disposed orifices in order to achieve a particular fluid flow. Conveniently, the control rod 18 may be cut short at one end so as not to extend through the end plate 30. The broken line 38 in FIG. 4 shows a convenient place for ending the rod 18 and the resulting force in chamber 14 acting on the end of rod 18 will provide a force sufficient to return the rod 18 to a particular start position which may be to the extreme left-hand side

as shown in FIG. 4. This avoids the use of a spring return in situations where the valve is required to have some bias back to a neutral or start position. A similar result can be achieved by using a rod which has different diameters on opposite sides of the control profile 20 such that the pressure area on opposite sides of the control profile 20 is unequal and a net force results.

In a further modification outlet control orifices 6 and 8 are arranged in the valve body 2 rather than in the wall of the spool 4 and thus connect the chambers 12 and 14 directly with the low pressure side of the hydraulic supply. With this modification the control orifices 6 and 8 may be made adjustable in size externally of the body part whereby the characteristics of the control valve, such as a response time for example, may be readily adjusted.

According to a still further modification the control spool 4 is directly connected to operate external machinery. In other words, instead of the control valve being used to operate equipment such as a hydraulic ram, for example, which in turn actuates some mechanical movement, the control valve may, in some circumstances, be used to directly actuate the mechanical movement.

It should also be noted that the control profile 20 which is shown in the described embodiment as being symmetrical in the longitudinal direction about a central transverse plane may, according to a modification, be asymmetrical in order to provide different characteristics for the opposite directions of movement of the control spool 4. The different characteristics may relate to response time or force, for example.

CLAIMS:

1. A fluid control device of the sliding spool type wherein a spool having various lands is adapted to slide within the bore of a body part to facilitate primary fluid flow between various main ports in said body part dependent upon the position of said spool, said spool having a longitudinal bore extending therethrough and means within said spool bore to facilitate fluid controlled movement of said spool, characterized in that, said means comprises a control profile having radial clearance in said spool bore and separating respective control chambers, each control chamber includes part of the bore of said body part whereby pressurized fluid in said control chambers exerts a force on respective ends of said spool, a first orifice arrangement is provided in said spool to facilitate secondary fluid flow from a pressure port of said main ports, through the wall of said spool and onto said control profile whereby said secondary flow is directed into respective said control chambers and, via further respective orifice arrangements, back to the low pressure side of a fluid supply such that said device is caused to act as a Wheatstone bridge tending towards equilibrium whereby said spool follows movement of said control profile along said spool bore in a force feedback gain manner due to imbalance of pressures in respective said control chambers.

2. A fluid control device as defi in claim 1, characterized in that said control profil s arranged on a control rod which extends to the outside of said body part for controlled movement from a transducer.

3. A fluid control device as defined in claim 2, characterized in that said control rod extends through opposite end plates of said body part and said control profile is arranged between the ends thereof.

4. A fluid control device as defined in claim 2, characterized in that, said control rod extends through an end plate of said body part and through one said control chamber and said control profile is arranged towards a free end of said rod, which free end is located in the other said control chamber whereby fluid pressure on said free end is adapted to provide a restoring force to restore said control profile to a start or neutral position.

5. A fluid control device as defined in claim 2, characterized in that, said control rod extends through opposite end plates of said body part and said control profile is arranged between the ends thereof, the diameter of said rod on one side of said control profile being larger than the diameter of said rod on the other side of said control profile.

6. A fluid control device as defined in claim 1, characterized in that, said further orifice arrangements are provided in said spool on opposite sides of said first orifice arrangement in the axial direction of said spool, to facilitate said secondary flow from said respective control chambers, through the wall of said spool to respective tank ports of said main ports and thereby back to said low pressure side of said fluid supply.

7. A fluid control device as defined in claim 1, characterized in that said further orifice arrangements are provided in said body part at opposite ends of said spool to facilitate said secondary flow from said respective control chambers, through the wall of said body part and back to said low pressure side of said fluid supply.

8. A fluid control device as defined in claim 7, characterized in that each said further orifice arrangement is adjustable to allow variation of the flow rate of said

secondary fluid flow whereby the operating characteristics of said spool may be varied to suit different applications of said device.

9. A fluid control device as defined in claim 1, characterized in that, said control profile is symmetrical, in the axial direction of said spool, whereby operating characteristics of said spool are the same in both directions of movement.

10. A fluid control device as defined in claim 1, characterized in that, said control profile is asymmetrical, in the axial direction of said spool, whereby operating characteristics of said spool are different for opposite directions of movement.

11. A fluid control device as defined in claim 1, characterized in that, said spool is adapted for connection, through an end plate of said body part, to actuate apparatus by virtue of the sliding movement of said spool.

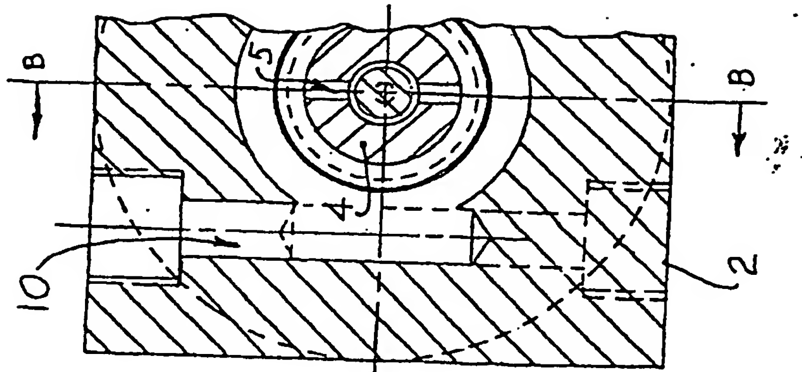

FIG. 2. Section AA

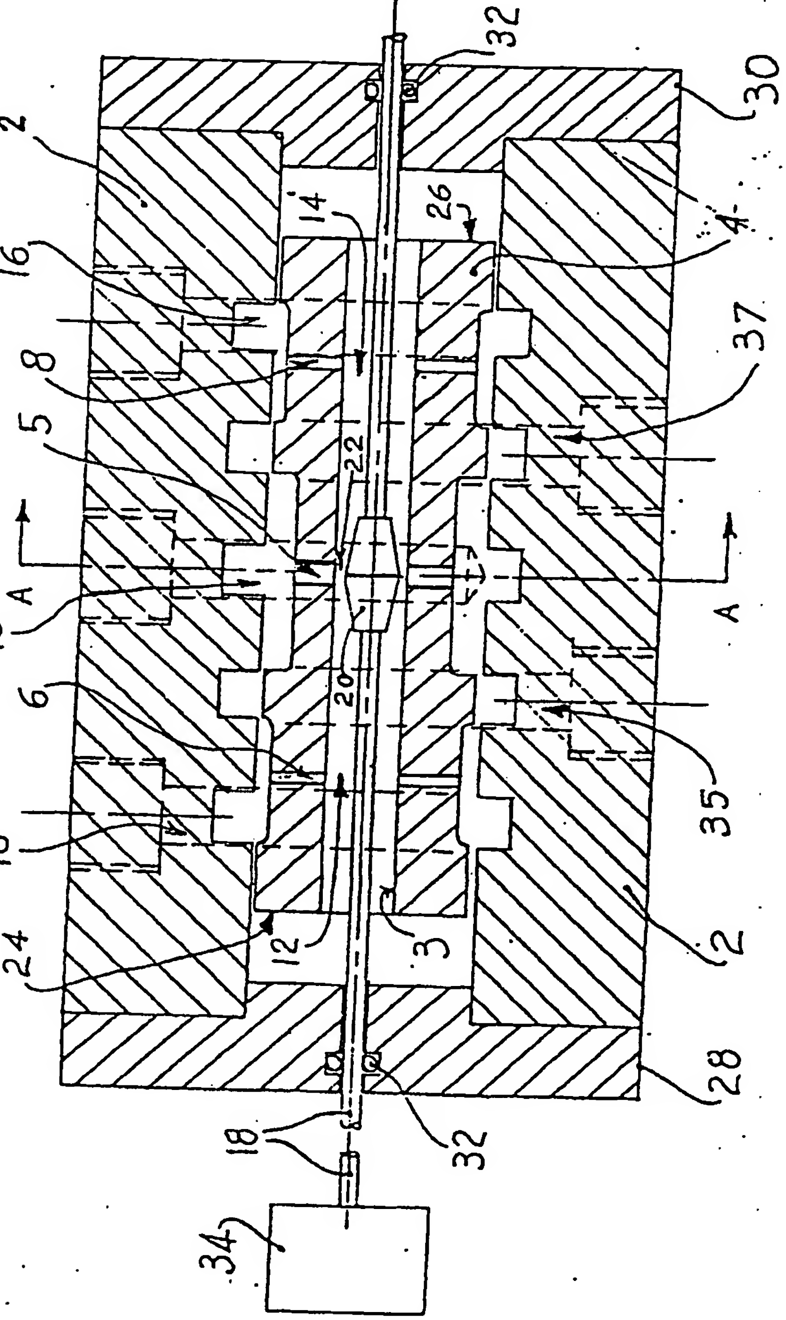

FIG. 1. Section B.B.

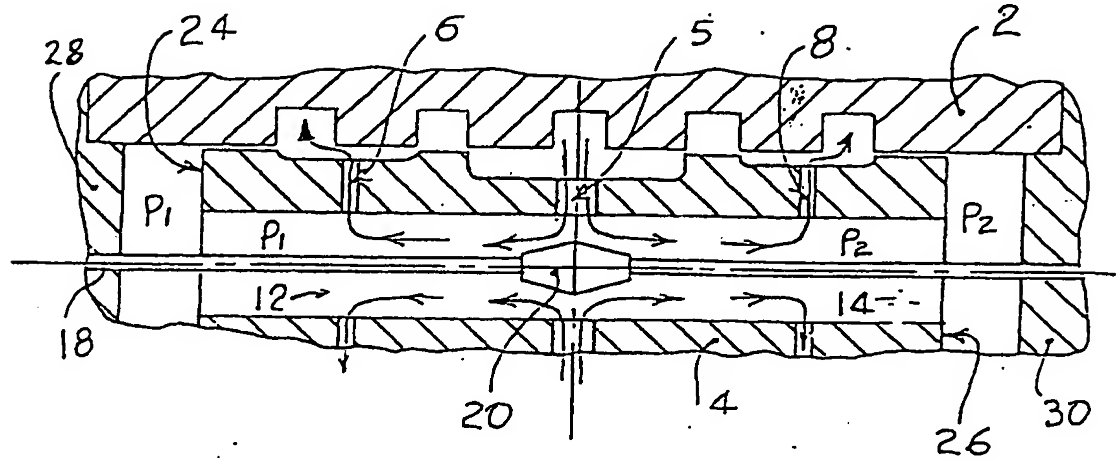

FIG. 3.

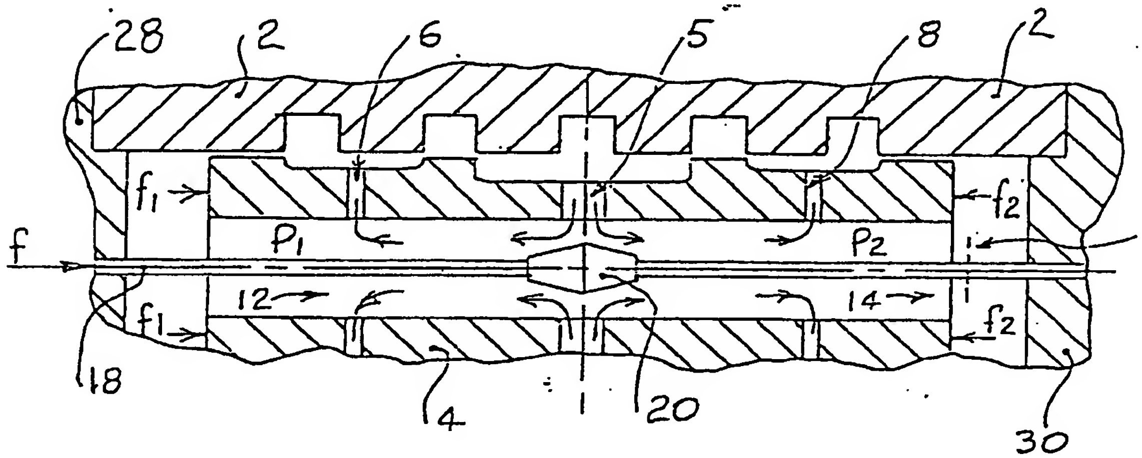

FIG. 4.

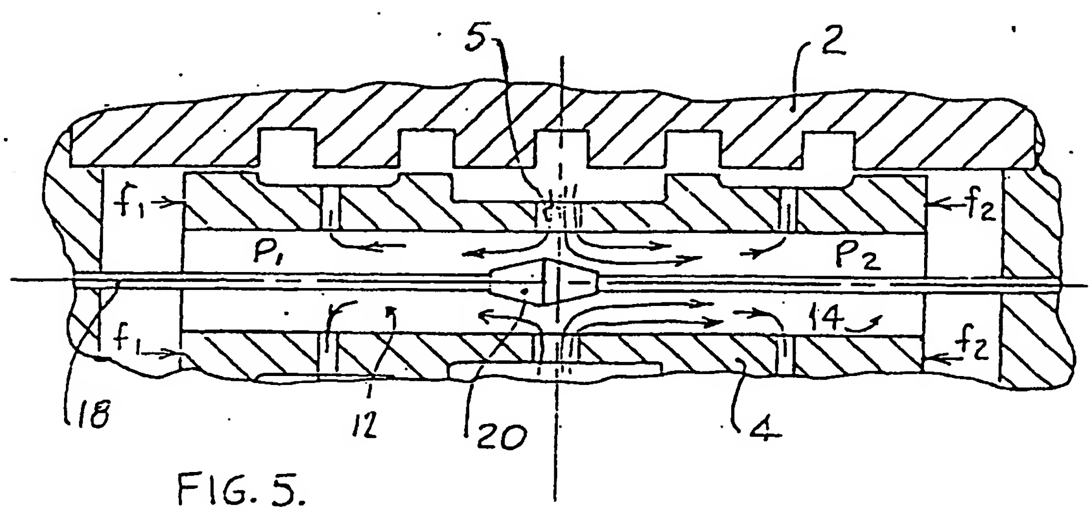

FIG. 5.

INTERNATIONAL SEARCH REPORT

International Application No PCT/AU 83/00036

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.[3] F16K 11/07

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
IPC	F16K 11/07
US Cl.	137/625.25

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

AU; IPC as above, Australian Classification 65 13,74.71.

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category*	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	US,A, 3990477 (JOHNSON) 9 November 1976 (09.11.76)	
A	US,A, 2836154 (LANTZ) 27 May 1958 (27.05.58)	
A	US,A, 2648313 (CLIFTON) 11 August 1953 (11.08.53)	
A	US,A, 2526361 (JOHNSON) 17 October 1950 (17.10.50)	
A	AU,B, 35814/71 (457387) (SPERRY RAND CORPORATION) 24 May 1973 (24.05.73)	
A	AU,B, 35113/68 (416920) (GENERAL SIGNAL CORPORATION) 25 September 1969 (25.09.69)	
A	AU,B, 29391/67 (432295) (BORG-WARNER CORPORATION) 8 May 1969 (08.05.69)	
A	AU,B, 450/61 (258411) (BALDWIN INSTRUMENT COMPANY LIMITED) 17 January 1963 (17.01.63)	

* Special categories of cited documents: [15]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [9]
3 JUNE 1983 (03.06.83)	08 June 1983 (08.06.83)
International Searching Authority [1]	**Signature of Authorized Officer [20]**
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